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Intelligent transport systems — Architecture — Applicability of data distribution technologies within ITS

Systèmes de transport intelligents — Architecture — Applicabilité des technologies de distribution des données dans les ITS

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Since the early 2000s, various study, design and prototype efforts have been undertaken to explore the potential use of communications in the vehicular environment. The first of these to demonstrate at real scale was the Vehicle Infrastructure Initiative (VII), which demonstrated short range wireless-based probe data generation and traveller advisory message delivery. This suggested the viability of initial vehicle-to-vehicle and vehicle-to-infrastructure communications.

Subsequent projects worked to more formally define the "glue" components necessary to enable widespread deployment. Several of these projects concluded that a publish-subscribe data distribution paradigm was a necessary component of any connected vehicle implementation of significant scale. These conclusions and much of the supporting work eventually found its way into ITS architectures. Much of this material is currently included in the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT)[6].

More recent pilot projects and deployments in both the United States and Europe have included publish-subscribe technologies, but no independent, objective analyses of the advantages and disadvantages of using specific protocols to facilitate data exchange within ITS are available. This document describes such an analysis.

Intelligent transport systems — Architecture — Applicability of data distribution technologies within ITS

1 Scope

A variety of general-purpose data distribution technologies have emerged within the Information and Communications Technologies (ICT) industry. These technologies generally provide services at the Open System Interconnect (OSI) session, presentation and application layers (i.e. layers 5-7). Within Intelligent Transport Systems (ITS), these layers roughly correspond to the facilities layer of the ITS station (ITS-S) reference architecture, as defined within ISO 21217.

This document investigates the applicability of these data distribution technologies within the ITS environment.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TS 14812, *Intelligent Transport Systems — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TS 14812 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
data distribution functionality
DDF
facilities layer (OSI layers 5, 6, and 7) functionality comprised of a set of data distribution services that enables distribution of data throughout a communication network controlled by a set of policies, regulations and rules

Note 1 to entry: Each distinct data distribution technology has its own unique data distribution functionality.

3.2
data distribution service
DDS
element of a set of services that implements a data distribution functionality in a communication network

EXAMPLE 1 Publish: the provision of data from one entity to another, where the receiving entity has previously registered to receive such data from the entity providing the data.

EXAMPLE 2 Subscribe: mechanism by which one entity registers for the reception of particular data from another entity.

EXAMPLE 3 Discovery: mechanism by which entities implementing DDF learn necessary particulars about how to communicate with one another (e.g. lower layer network address, ports, etc.).

Note 1 to entry: This is a specific protocol standardized by the OMG.

4 Abbreviated terms

AES	Advanced Encryption Standard
AMQP	advanced message queuing protocol
API	application programming interface
ARC-IT	architecture reference for cooperative and intelligent transportation
ASN.1	abstract syntax notion one
AUTOSAR	automotive open system architecture
C-ITS	cooperative ITS
C2C	centre-to-centre
C2F	centre-to-field
C2P	centre-to-personal station
C2V	centre-to-vehicle
C2X	centre-to-anything
CoAP	constrained application protocol
ConOps	concept of operations
CSSDDS	commercial source software DDS
CSV	comma separated value
DSRC	dedicated short range communications
FEP-SDK	functional engineering platform software development kit
FIPS	Federal Information Processing Standard
HARTS	harmonized architecture reference for technical standards
HTTP	hypertext transfer protocol
IANA	internet assigned numbers authority
ICD	interface control document
ICT	information and communications technology
IDL	interface definition language
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers

IoT	internet of things
IP	internet protocol
ISO	Organization of International Standardization
ITS	intelligent transport systems
ITS-S	ITS station
ITS-SU	ITS station unit
JMS	Java Message Service
JSON	Javascript Object Notation
MQTT	message queuing telemetry transport
NTCIP	National Transportation Communications for ITS Protocol
OMG	object management group
OASIS	Organization for the Advancement of Structured Information Standards
OS	operating system
OSI	open system interconnect
OSS DDS	open source software DDS
PHP	hypertext preprocessor
REST	representational state transfer
RSS	really simple syndication
SNMP	simple network management protocol
SOAP	simple object access protocol
STOMP	simple text-oriented messaging protocol
TCP	transport control protocol
TLS	transport layer security
UDP	user datagram protocol
UML	Unified Modeling Language
V2I	vehicle-to-infrastructure (communications)
VII	vehicle infrastructure initiative
V2V	vehicle-to-vehicle (communications)
XML	Extensible Markup Language
XMPP	Extensible Messaging and Presence Protocol

5 Transitioning from traditional to cooperative thinking

5.1 General

5.1.1 Need for data exchanges

ITS is heavily dependent upon the exchange of various types of data between and among disparate types of physical entities. As described within the Architecture Reference for Cooperative and Intelligent Transportation (see Reference [6]), such entities include:

— centres (e.g. fixed-location facilities and cloud-based back-office services);

— field devices (e.g. devices along the roadside);

— vehicles;

— travellers (e.g. personal devices);

— support systems (typically fixed or back-office, that provide services enabling ITS, but do not directly provide ITS services).

The data that these systems exchange include:

— live elemental data (e.g. vehicle speed, location, signal timing information, device status, etc.);

— live aggregated data (e.g. average speeds, rain rates, etc.);

— status information (e.g. status of reversible flow lanes);

— (relatively) static data (e.g. map information);

— quasi-static information (e.g. road conditions, weather);

— exception reports (e.g. information on traffic incidents, realignment of lanes due to incidents or road work, etc.);

— control and configuration data (e.g. device control, software configuration);

— coordination data (e.g. exchanges to coordinate a response plan among centres);

— traffic regulations;

— software updates (e.g. for on-board applications);

— security material distribution including certificates and revocation lists.

Entities exchange data according to some well-characterized patterns. Certain kinds of entities typically exchange certain kinds of data, and some characteristics of those exchanges tend to be relatively consistent for similar kinds of data. For example:

— centres provide control and configuration data to field devices. These exchanges tend to be synchronous request-response-based exchanges and occur irregularly;

— centres exchange coordination data with one another. These exchanges vary in size and format and occur irregularly;

— field devices provide elemental and aggregated data to centres. These exchanges tend to be periodic and are often redistributed centre-to-centre;

— centres provide exceptional information to field, vehicle, and personal devices. As exceptions, these are irregular. The information is often geo-centric and needs to be disseminated to all entities within a defined area that can benefit from such information, such as the dissemination of traffic incidents to all vehicles upstream of the incident;

— centres provide information of wide utility (e.g. traffic regulations) to all vehicles in a geographic area. These exchanges vary in size, can be initiated by either party depending on the communications regime and are typically motivated by the geo-location of the vehicle or personal device;

— vehicles provide live and aggregated data to field devices and centres. These exchanges are typically periodic and can be pseudonymized.

Additionally, some of the information exchanged can be useful for supporting ITS services other than the ITS service for which the data was originally intended. Some of the information acquired and exchanged between entities when implementing a specific ITS service also has potential value outside ITS.

The challenges inherent in attempting to efficiently share information are two-fold. First, information has value; often those involved in the acquisition will attempt to retain ownership of and control over such information and to minimize privacy issues. Second, assuming the information can be made available from the source, the technical challenge arises of getting the information to the right places at the right times while implementing the established privacy policies. This document addresses the later issue, The former issue is addressed by regulatory entities and other stakeholders in the ITS community.

There are a variety of technical and institutional challenges related to successfully sharing data in a timely and secure manner. These challenges include:

— acquiring the data (e.g. through sensors);

— defining ownership and access rights for the data;

— securing the data (e.g. authentication, authorization, confidentiality, integrity, availability, etc.);

— achieving adequate market penetration of lower-layer communication technologies;

— agreeing on the upper-layer protocols for exchanging the data over the communication technologies;

— standardizing the definition of data for use in various contexts;

— defining performance criteria for different uses of the data;

— maintaining the interface over the life cycle of the involved physical objects. Operational lifetimes for ITS devices vary radically: field devices often have lifetimes of 15-20 years, vehicles closer to 10 (although often much longer) and smartphones can be as short as 18 months.

5.1.2 Data distribution functionality

A data distribution functionality (DDF) is implemented as a set of facilities layer (OSI layers 5, 6, and 7) services that enables distribution of data throughout a communication network controlled by a set of policies, regulations and rules. Through a standardized application programming interface (API), application processes can request information from (subscribe) and offer information to (publish) the communication network to which they are attached without needing to know anything about the details of how the information transfers take place. Using metadata and service configuration requests, a variety of policies, rules and regulations can be implemented. When using DDF, application processes no longer need to directly create and consume messages with other application processes to affect information exchange. Instead, application processes publish data they agree to share (and receive data they are interested in) through an API without having to know anything about the final destination(s) (or source) or having to conform to a particular message format for each end entity.

NOTE The Object Management Group (OMG) has created a set of standards for data distribution functionality (see 3.1) called the Data Distribution Service (DDS). This document uses the term “OMG DDS” to refer to OMG’s understanding of data distribution functionality and the term “DDF” to refer to a generic data distribution functionality.

5.2 Systems engineering process

5.2.1 Conceptualization

The systems engineering approach to designing any complex system is to work with the relevant stakeholders, including service providers and system integrators, to develop a “concept of operations”, or ConOps. This involves describing in detail the service (the “why”), the actors participating in the service (the “who”), and the requirements on information to be generated and exchanged by entities engaged in the service (the “what”).

Once agreement is reached on the ConOps, the implementers work together to develop a high-level design (i.e. an architecture) that defines the means by which the service will be implemented (the “how”), which (directly or indirectly) defines the details of how the information is encoded and transferred between physical objects. If the system is intended to support an open interface (i.e. so that competing manufacturers can interoperate), these design details need to be defined within open standards and developed with broad-based consensus.

5.2.2 System architecture

An architecture description of a specific system of interest can leverage existing work (e.g. reference architectures such as ARC-IT) to simplify the organization of content, provide a common language reference and assist in identifying implementation-relevant artifacts, in particular interfaces as well as the standards used to implement endpoints and interfaces. The reference architecture can illustrate where many information exchanges overlap or group together in patterns, which would suggest an opportunity for consolidation that is relevant to a DDF.

For example, if several information flows all have the same source and destination, then perhaps those information flows can share a DDF technology to provide some aspects of the information exchange. These patterns will generally become clear if a system architecture is illustrated.

The system architecture development process can suggest design paradigms for interfaces, where some interfaces are traditional ‘mesh’ interfaces (custom at each end), while others use a DDF to provide transport, publication and subscription management, with or without a hub/broker. More complex involvements can require hierarchies, which can be best noted if data dependencies are clearly shown.

5.2.3 System design

Open system design activities focus on developing interface control documents (ICDs), which specify the:

— rules for application processes needing to share data;

— data elements to be exchanged;

— messages that contain those elements;

— dialogues and patterns of message exchange, which suggest or require behaviours at end points;

— lower layer details (i.e. details of the network and transport layer and access layer of the ITS-S architecture).

Each DDF specification provides the messaging and dialogue components of the ICD. In many cases, other standards will define the other aspects of the ICD and the ICD itself becomes primarily a reference to a series of standards. Using DDF provides significant savings because it relies upon a single standard interface for exchanging any data rather than requiring specialized messages for each interface.

5.3 Traditional silos versus cooperative approaches

Once the architecture is developed, each interface is designed by its own group of experts to meet the defined needs. However, this division of effort tends to produce "silos" of thought that can often result in four major problems:

1) Competing protocol selection: Different silo efforts are likely to select different approaches to exchanging data. There are many off-the-shelf protocols that can be extended to support most ITS data exchange needs and some experts can wish to develop their own protocols to optimize performance in certain cases. While each decision can be reasonable in isolation, each protocol adopted by the ITS industry has costs associated with stakeholders learning the technology, implementers programming with the technology, testers verifying conformance to the technology, and maintenance issues with maintaining backwards compatibility, as well as memory and processing issues within devices that need to support multiple technologies. Ideally, the ITS community as a whole can attempt to identify a suite of preferred protocols that meet industry needs so that the variability in systems is minimized.

2) Competing data definitions: Different silo efforts are likely to produce different data definitions to describe the same real-world conditions. This greatly complicates data sharing, increases potential translation errors, and increases integration costs. Ideally, all ITS data definitions can be developed in a cooperative fashion.

3) Limited scope and lack of forwards compatibility: Engineers within the silo teams often attempt to "optimize" their design; however, without a complete knowledge of how data can be used, it is impossible to know if a design is truly optimal or not. This can partially be overcome by ensuring that the reference architecture is developed with as broad a scope as practical, but since innovations occur over time, no effort can be omniscient about how the data will be used; one can only attempt to consider as much data as possible.

4) Competing efforts: A final challenge facing any development team is that there are often different competing and/or overlapping efforts across the world. Once standards are developed, it is often difficult and expensive to harmonize the results at a later point.

This document attempts to address the first issue by identifying different protocols that have been suggested for use within the ITS industry, comparing their respective characteristics, and suggesting a preferred set of protocols for future use.

6 Summary of needs and considerations

6.1 General

In order to evaluate specific technologies, the analysis described in this document began by identifying the key stakeholder needs and considerations for data distribution. Recognizing that the needs of ITS vary based on the specific information flow considered, an analysis of the Harmonized Architecture Reference for Technical Standards (HARTS; see Reference [9]) and ARC-IT v8.3 (see Reference [6]) was performed to identify the types of information flows throughout ITS and to determine the possible characteristics driving the selection of data exchange technology.

6.2 Types of information flows

6.2.1 General

Information flows were characterized by general pattern of information exchange. Those types were then assessed for whether they might be appropriate for satisfaction through a data distribution system. Note that these categorizations attempt to cover 80 % or more of the information flows in ARC-IT, but do not pretend to be an exhaustive and complete assessment.